RELIEF DEVICE DESIGN

VALVE BOX AND CRYOSTAT

There are some anomalus stress that the solenoid must sustain without damaging itself.

a) RUPTURE IN LIQUID HELIUM LINE → rule CGA S-1.3 § 4.9.1.1

b) PRESSURE INCREASE DUE TO FIRE CONDITION in liquid helium line → rule: CGA S-1.3 § 5.3.5

c) LOSS OF VACUUM → rule CGA S-1.3 § 4.9.1.1

d) VACUUM VESSEL RELIEF DEVICE → rule CGA 341 § 6.4.2

For the design it was used two references:

1) The Appendix A of the book "Thecnology of liquid helium" treating the **"Sizing of relief devices"** relates to the CGA rules and investigates in detail the following cases:

   - Sizing for fire condition
   - Loss of vacuum (no fire)

2) "SAFETY ASPECTS FOR LHE CRYOSTAT AND LHE TRANSPORT CONTAINERS" by W. Lehmannn and G. Zahn ICEC7

02/12/96 19:32 ANSALDO ENERGIA (PMA) GENOVA → 5104226747 NO.007 D03

GENERAL EQUATION

Qa = const. (UA(t2 - t))) → UA(t2 - t) is the heat power going to the surface of liquid helium.

or

Qa = Gi(@1200 F) U A

with:

Qa = flow capacity in cubic feet per minute of free air
t2 = temperature of external wall in F
t = temperature of gas at flow condition in F
Gi = gas factor for insulated container
U = (Thermal conductivity of insulation / thickness of insulation) in Btu/(hr ft2 F)
A = total outside surface area of the container in square feet

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a) LOSS OF VACUUM with helium

The rule gives a minimum required capacity of the pressure relief valve for helium line:

$$Qa = (130 - t) / 4(1200 - t) * Gi\ U\ A$$

From ref. 1 for helium asssuming:

relief valve pressure of 70 psig (5.8 abs bar)

↓

$Qa = 0.00787\ (UA\ (100 - t))$ with:

$t = -445$ F (8.15 K)

or

$Qa(Nm3/h) = 0.0455\ P(W)$

$P = k\ int.(80K-4.2K)\ A/l = 363$ W with:

k int = 2.91 W/m
A = 7.86 m2
l = 0.063 m

Qa = 16.5 (Nm3/h) of air

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b) FIRE CONDITION (with helium in insulation)

From ref. 1

$Qa = Gi\ U(100\ F)\ A^{0.82}$ with:

Gi = 52.5

l (300K- 4.2K) = 0.135 m

U = k(100 F)/ l = 0.16 / 0.135 = 1.19 W/(m2 K) = 1.19*0.305/1.73 = 0.210 BTU/ft2 h F

A = 7.86 m2 = 84.6 ft2

Qa = 420 SCFM of air = 420 * 0.0283 * 60 = 713 Nm3/h of air

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c) LOSS OF VACUUM with air

From ref. 2

P = (cryost. with superinsulation) 50 kW

Qa = 2275 Nm3/h of air

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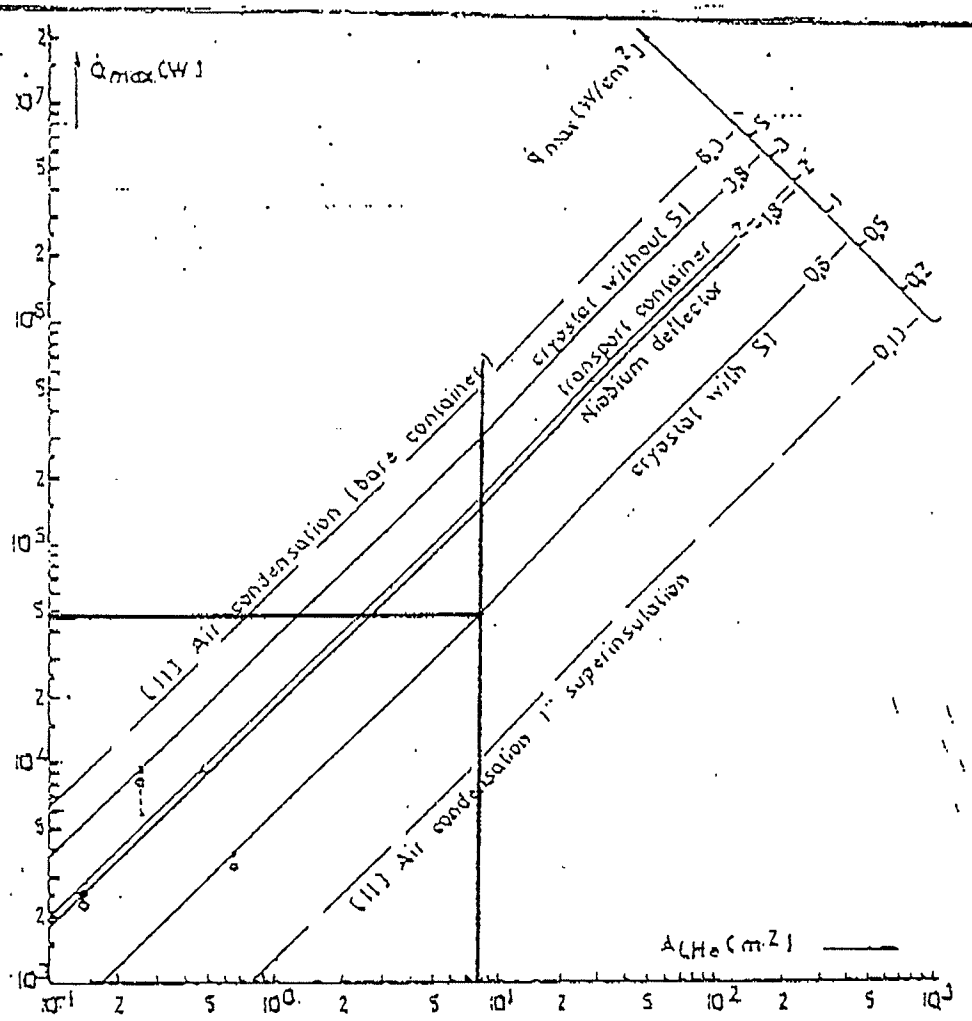

▪ Cryostat without superinsulation (• calculated), ▴ LHe transport container;
• Cryostat with superinsulation (∘ calculated), ◆ Niob deflector (∘ calculated)

: Scaled heat load based on measurements with the test objects. Comparison with our calculations and estimations of [11].

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d) VACUUM VESSEL RELIEF DEVICE

rule CGA 341 § 6.4.2 → Discharge area > 0.34 mm2/kg of the water capacity

P set point < 1.6 bar g

V tot = V cryo + V valve box + V chimney - V cold mass

V cryo = 13500 l
V valve box = 555 l - 32 l = 523 l
V chimney = 65 l
V cold mass = 2490 l + 23 l = 2513 l

V tot = 11575 l
P water = 11575 kg
Discharge area = 0.34 * 11575 = 3935 mm2

Φ > 71 mm → DN 100 ISO K

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CONCLUSION

RELIEF DEVICE for helium pipe

Qa max > 2275 Nm3/h of air

↓

DN 40 in / DN(50 out) → 2657 Nm3/h = kg/h

65 out

RELIEF DEVICE for vacuum vessel

Φ > 71 mm

↓

DN 100 ISO K → Φ = 100 mm

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				LIQUID AND TOTAL HELIUM VOLUME						
									SINGLE	TOTAL
								mm3		
height liquid lead	mm	hll	316		volume liquid lead		vll	4.39E+06	4.4	8.8
height lead	mm	hl	367		volume total lead		vl	5.10E+06	5.1	10.2
diameter lead	mm	dl	133							
number leads		nl	2							
								mm3		
height liquid reservoir	mm	hlr	266		volume liquid reservoir		vlr	1.39E+07	13.9	13.9
height reservoir	mm	hr	417		volume total reservoir		vr	2.18E+07	21.8	21.8
diameter reservoir	mm	dr	258							
diameter pipe circuit	mm	dci	20		lenght 1 circuit	mm	lci	5.06E+03		
diameter circuit	mm	dc	3220		section circuit	mm2	sc	3.14E+02		
number circuits		nci	22		volume circuit		vci	1.59E+06	1.6	34.9
lenght collector	mm	lco	3500							
section collector	mm2	sco	1656		volume collector		vco	5.80E+06	5.8	11.6
number collector		nco	2							
					volume liquid		vli	6.92E+07	69.2	
					volume total		vt	7.85E+07	78.5	
		mm	mm2	m2						
surface leads	sl		3.34E+05	0.33430481						
surface reservoir	sr		3.90E+05	0.39007278						
diameter external pipe circuit	dce	30.0								
surface circuits	sci		1.05E+07							
surface exposed outside	sci_o		7.86E+06	7.85760822						
surface collector	sco		trasc.							
surface total	st		1.91E+07	8.58198581						

$V_{CI} > V_L + V$

$$\boxed{V_L + V_R}$$

VOLU-HE.XLT

RIA (0°C)	PORTATE IN Kg/h CON SOVRAPPRESSIONE DEL 10% (Formule ISPESL Raccolta E)
AIR (0°C)	Kg/h DELIVERIES WITH 10% OVERPRESSURE (ISPESL Formulas Collection E)
AIR (0°C)	DÉBITS EN Kg/h AVEC SURPRESSION DU 10% (Formules ISPESL Récolte E)
LUFT (0°C)	DURCHFLÜSSE IN Kg/h BEI 10% ÜBERDRUCK (ISPESL-Formeln Sammlung E)
[illegible]	TIPO DI VALVOLA E AREA DI ENTRATA

VAPORE SATURO	PORTATE IN Kg/h CON SOVRAPPRESSIONE DEL 10% (Formule ISPESL Raccolta E)
SATURED VAPOR	Kg/h DELIVERIES WITH 10% OVERPRESSURE (ISPESL Formulas Collection E)
VAPEUR SATURÉE	DÉBITS EN Kg/h AVEC SURPRESSION DU 10% (Formules ISPESL Récolte E)
SATTDAMPF	DURCHFLÜSSE IN Kg/h BEI 10% ÜBERDRUCK (ISPESL-Formeln Sammlung E)
PRESSIONI DI RELATIVE	TIPO DI VALVOLA E AREA DI ENTRATA

AIR (0°C)	DÉBITS EN Kg/h AVEC SURPRESSION DU 10% (Formules ISPESL Récolte E)
LUFT (0°C)	DURCHFLÜSSE IN Kg/h BEI 10% ÜBERDRUCK (ISPESL-Formeln Sammlung E)

PRESSIONE DI TARATURA IN bar RELATIVI / PRESSION D'ETALONNAGE EN bars RELATIFS	RELATIVE bar CALIBRATION PRESSURE / HÖCHDRUCK IN BAR ÜBERDRÜCKEN	TIPO DI VALVOLA E AREA DI ENTRATA / TYPE OF VALVE AND INLET AREA / TYPE DE SOUPAPE ET ZONE D'ADMISSION / VENTILTYP UND ZUFLUSSBEREICH					
		15/20	20/25	25/32	32/40	40/50	50/65
		0,866	1,431	2,270	3,630	5,515	9,079
0,5		101	167	265	423	643	1060
1		136	225	357	571	867	1428
1,5		171	283	449	718	1091	1796
2		206	341	541	866	1351	2165
2,5		241	399	633	1012	1538	2533
3		276	457	725	1160	1762	2901
3,5		311	515	817	1307	1986	3270
4		347	573	909	1454	2209	3638
4,5		382	631	1001	1601	2433	4006
5		417	689	1093	1749	2657	4375
6		487	806	1277	2043	3104	5111
7		557	921	1462	2338	3552	5848
8		628	1037	1646	2632	3999	6585
9		698	1153	1830	2927	4447	7321
10		768	1270	2014	3221	4894	8058
11		838	1386	2198	3516	5342	8795
12		909	1502	2382	3810	5789	9531
13		979	1618	2567	4105	6236	10268
14		1049	1734	2751	4399	6684	11005
15		1119	1850	2935	4694	7131	11741

VAPEUR SATURÉE	DÉBITS EN Kg/h AVEC SURPRESSION DU 10% (Formules ISPESL Récolte E)
SATTDAMPF	DÜRCHFLÜSSE IN Kg/h BEI 10% ÜBERDRUCK (ISPESL-Formeln Sammlung E)

PRESSIONE DI TARATURA IN bar RELATIVI / PRESSION D'ETALONNAGE EN bars RELATIFS	RELATIVE bar CALIBRATION PRESSURE / HÖCHDRUCK IN BAR ÜBERDRÜCKEN	TEMPERATURA TEMPERATURE °C	TIPO DI VALVOLA E AREA DI ENTRATA / TYPE OF VALVE AND INLET AREA / TYPE DE SOUPAPE ET ZONE D'ADMISSION / VENTILTYP UND ZUFLUSSBEREICH					
			15/20	20/25	25/32	32/40	40/50	50/65
			0,866	1,431	2,270	3,630	5,515	9,079
0,5		111,6	61	101	161	258	391	644
1		120,4	81	134	213	341	519	854
1,5		127,6	101	168	266	426	647	1064
2		133,7	121	200	318	508	772	1271
2,5		139,0	141	233	369	591	897	1477
3		143,7	161	266	421	673	1023	1683
3,5		148,7	180	297	472	754	1146	1887
4		152,0	200	330	523	837	1271	2093
4,5		155,5	219	362	574	916	1396	2297
5		158,9	238	394	625	1000	1519	2501
6		165,0	277	458	727	1163	1767	2909
7		170,5	316	522	828	1324	2012	3312
8		175,4	354	585	928	1485	2256	3714
9		180,0	393	650	1031	1648	2504	4122
10		184,1	432	714	1132	1810	2750	4528
11		188,0	470	777	1232	1971	2994	4929
12		191,7	508	840	1333	2132	3238	5331
13		195,1	546	902	1432	2290	3478	5726
14		198,3	584	965	1532	2450	3722	6127
15		201,4	623	1029	1633	2611	3966	6530

ACQUA SURRISCALDATA	PORTATE IN Kcal/h CON SOVRAPPRESSIONE DEL 10% (Formule ISPESL Raccolta E)
OVERHEATED WATER	Kcal/h DELIVERIES WITH 10% OVERPRESSURE (ISPESL Formulas Collection E)
EAU SURCHAUFFÉE	DÉBITS EN Kcal/h AVEC SURPRESSION DU 10% (Formules ISPESL Récolte E)
DRUCKHEISSWASSER	DÜRCHFLÜSSE IN Kcal/h BEI 10% ÜBERDRUCK (ISPESL-Formeln Sammlung E)

PRESSIONE DI TARATURA IN bar RELATIVI / PRESSION D'ETALONNAGE EN bars RELATIFS	RELATIVE bar CALIBRATION PRESSURE / HÖCHDRUCK IN BAR ÜBERDRÜCKEN	TIPO DI VALVOLA E AREA DI ENTRATA / TYPE OF VALVE AND INLET AREA / TYPE DE SOUPAPE ET ZONE D'ADMISSION / VENTILTYP UND ZUFLUSSBEREICH					
		15/20	20/25	25/32	32/40	40/50	50/65
		0,866	1,431	2,270	3,630	5,515	9,079
1		43007	71329	113287	180944	275349	453146
1,5		53506	88312	140779	224936	341818	563116
2		63796	105469	167722	268047	407472	671403
2,5		74021	122517	193986	310357	471692	776964
3		83736	139063	221266	352707	536912	882021
3,5		93680	155077	245706	393230	597146	983336
4		103103	170170	270270	432431	657165	1081578
4,5		112435	186066	295019	472129	717398	1181567
5		121694	202166	320591	512846	778932	1282364
5,5		131420	217196	344755	551608	837754	1379612
6		140776	232992	369363	591063	897631	1477904
6,5		149666	247655	393422	628890	955524	1573689
7		157792	260721	418028	668853	1015695	1672596
7,5		168264	278022	440967	705993	1072438	1765317
8		177199	293244	464865	743484	1129641	1860104
8,5		186064	307852	488151	781138	1186332	1953364
9		194629	322327	511426	817995	1242990	2046669
9,5		203524	336671	534489	854993	1299131	2138432
10		212613	351356	557340	891176	1354284	2229260
11		229600	379380	601937	963006	1463525	2409158
12		246798	408216	647648	1036170	1574082	2591591
13		263752	436651	692823	1107387	1682638	2770090
14		280929	464223	736402	1178089	1790116	2946628
15		297402	491858	780109	1246174	1896054	3121360

ACQUA CALDA (max 100°C)	PORTATE IN Kcal/h (Formule ISPESL Raccolta E)
HOT WATER (100°C max)	Kcal/h DELIVERIES (ISPESL Formulas Collection E)
EAU CHAUDE (100°C max)	DÉBITS EN Kcal/h (Formules ISPESL Récolte E)
HEISSWASSER (max 100°C)	DÜRCHFLÜSSE IN Kcal/h (ISPESL-Formeln Sammlung E)

PRESSIONE DI TARATURA IN bar RELATIVI / PRESSION D'ETALONNAGE EN bars RELATIFS	RELATIVE bar CALIBRATION PRESSURE / HÖCHDRUCK IN BAR ÜBERDRÜCKEN	TIPO DI VALVOLA E AREA DI ENTRATA / TYPE OF VALVE AND INLET AREA / TYPE DE SOUPAPE ET ZONE D'ADMISSION / VENTILTYP UND ZUFLUSSBEREICH					
		15/20	20/25	25/32	32/40	40/50	50/65
		0,866	1,431	2,270	3,630	5,515	9,079
1		38761	64060	101603	162476	246847	406414
2		57627	95259	150792	241135	366383	603171
3		75804	124765	197915	316490	480839	791662
4		94135	156551	246751	394850	599487	987007
5		111814	184268	292306	467432	710166	1169224
6		129436	213883	339263	542558	824295	1357136
7		147926	244438	387753	620063	942052	1551012
8		166667	275645	441868	706583	1073501	1767432
9		186666	307114	487176	779053	1183603	1948707
10		201546	332707	527775	843975	1282237	2111100
11		219649	362953	575754	920700	1398804	2303018
12		241814	399249	633330	1012770	1538688	2533320

bar RELATIVI / RELATIVE bar / bar RELATIFS / BAR ÜBERDRÜCKEN	M	bar RELATIVI / RELATIVE bar / bar RELATIFS / BAR ÜBERDRÜCKEN	M
1	1,87	7	0,49
2	1,26	8	0,43
3	0,96	9	0,39
4	0,77	10	0,36
5	0,65	11	0,33
6	0,56	12	0,30